Preface

Subsequent to the studies on precursor lead-acid systems by Daniel, Grove and Sindesten, practical lead-acid batteries began with the research and inventions of Raymond Gaston Planté in France as early as in 1859, and, even to-day, lead-acid battery remains the most successful battery system ever developed, and no other battery is yet able to compete with lead-acid batteries on cost grounds, albeit batteries based on other chemistries are rapidly catching up.

In the past, although lead-acid battery designs have been optimized in several different directions, there are still certain new challenges facing the lead-acid battery designers as additional failure modes become evident in various use modes. There are three types of lead-acid batteries in common use: (a) batteries with flooded or excess electrolyte, (b) low-maintenance lead-acid batteries with a large excess of electrolyte, and (c) batteries with immobilized electrolyte and a pressure-sensitive valve usually referred to as absorptive glass-microfibre (AGM) valve-regulated lead-acid (VRLA) batteries.

The flooded-electrolyte lead-acid battery requires checking of specific gravity of electrolyte, periodic addition of water to maintain electrolyte level above the plates and recharge soon after discharge to prevent hard sulfation that causes loss of capacity. The emission of acid fumes corrodes metallic parts in the vicinity of the battery, and the seepage of acid on the top cover of the batteries leads to leakage current resulting in increased self-discharge and ground-shunt hazards. To overcome these problems, AGM-VRLA batteries based on oxygen-recombination cycle have emerged. These batteries offer the freedom of battery placement, cyclability without the addition of water or checking the specific gravity, increased safety, and superior performance in some instances. Both flooded-electrolyte and AGM-VRLA batteries can suffer from acid stratification. But, AGM-VRLA batteries are especially susceptible to failures owing to the heat generated by oxygen recombination within the cells as well as due to cell-to-cell variations in electrolyte volumes. Indeed, partial heating of AGM-VRLA batteries could cause dry-out with grid corrosion and even lead to thermal runaway. Consequently, mitigating temperature variations in AGM-VRLA batteries becomes seminal to their commercial success. A dissipation of local heat within the AGM-VRLA batteries can be achieved by adequately filling the void volume in the battery with a thermally conducting gel, such as a gel formed from colloidal silica and sulfuric-acid electrolyte.

Although, conventional lead-acid batteries are considered rather a matured technology, significant research and development efforts are currently under way to enhance their performance. Indeed, many improvements have been made in the lead-acid battery since its invention, and although the essential electrochemistry remains unchanged, the modern lead-acid batteries have little semblance to those produced 50 years ago. Over the years, seminal advances have been made in the lead-alloys used, in the materials and design of separators, in battery packaging and in their construction methods, which have led to lead-acid batteries with improved performance, lighter weight and lower cost.

This thesis is an attempt to develop lightweight hybrid-VRLA batteries.